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Lakehurst, New Jersey

08733

EVALUATION OF LOW-MODULUS NYLON AND ENERGY-ABSORBING STAINLESS-STEEL DECK PENDANTS USED WITH THE E-28 ARRESTING-GEAR SYSTEM

(24 August 1970 through 24 June 1971)

Final Report
30 September 1971

by

John J. Schaible
Recovery Division

Prepared under U.S. Air Force
MIPR FX-2826-70-05259

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NAVAL AIR TEST FACILITY
NAVAL AIR STATION
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ABSTRACT

The Air Force, which requires a higher engaging-speed capability for its lightweight fighter aircraft, selected to evaluate (through deadload tests) various low-modulus deck pendants as a means of reducing the dynamic arresting-hook loads which occur during arrestments of lightweight fighter aircraft.

In addition to pendant performance, simulated aircraft main-wheel-rim rollovers of the pendants were conducted to determine the extent of pendant damage incurred and various types of pendant-to-purchase-tape connecting hardware were evaluated.

One hundred sixty-three arrestments were conducted ON-CENTER and 35 feet OFF-CENTER to port at engaging speeds ranging from 114 to 233 knots. Twelve rollovers were conducted at a speed of approximately 100 knots.

The arresting-hook loads obtained when using low-modulus nylon and energy-absorbing stainless-steel pendants were 35 and 25 percent lower, respectively, than those obtained when using the standard steel pendant.

Based on these results, it is possible to increase the engaging-speed limit of lightweight fighter aircraft to 230 knots.

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I INTRODUCTION

A. The U. S. Air Force desires to increase the engaging-speed capability of its lightweight fighter aircraft. In order to do this, the dynamic arresting-hook loads that occur during arrestments of lightweight fighter aircraft must be reduced. Reference (a) authorized the NATF (Naval Air Test Facility) to test and evaluate low-modulus nylon and energy-absorbing stainless-steel deck pendants for the U. S. Air Force. These pendants, designed to reduce initial impact loads which limit the engaging speed of lightweight fighter aircraft, were tested and evaluated during the period of 11 September 1970 through 24 June 1971. The primary purpose of the test program was to determine the optimum pendant in terms of lowest impact hook loads.

B. In addition to the above, simulated aircraft main-wheel-rim rollover tests were conducted to determine the extent of pendant damage incurred by such rollovers and different types of pendant-to-purchase-tape connectors were evaluated.

C. The Navy E-28 arresting-gear system, installed on a 225-foot deck span, and a 25,000-pound deadload were used during the test program which consisted of 175 events: 138 arrestments ON-CENTER, 25 arrestments 35 feet OFF-CENTER, and 12 main-wheel-rim rollovers. The arrestments were conducted at speeds ranging from 114 to 233 knots, and the rollovers were conducted at approximately 100 knots.

D. The first phase of the test program was to establish base-line data using a standard steel pendant. Next, nylon pendants (supplied by E. W. Bliss Company, Goodyear Tire and Rubber Company, and All American Engineering Company) and energy-absorbing stainless-steel pendants (supplied by the American Chain and Cable Company) were tested and the results were compared with the base-line data. Finally, the various pendants utilized for the preceding tests were then used for the simulated aircraft main-wheel-rim rollover tests.

II TEST EQUIPMENT

A. Arresting-Gear System

1. Operation: The E-28 arresting-gear system consists of one rotary hydraulic energy absorber and one deck-sheave assembly located on each side of the runout area. One purchase-tape storage reel is located on top of each absorber unit.

a. The energy of the arrested vehicle is transmitted through a deck pendant to the purchase tapes. The forward motion of the vehicle pulls the purchase tape off the reel, thereby rotating the extended shaft of the energy absorber. A 43-1/2-inch-diameter, nine-vaned rotor and the purchase-tape drum are splined to this shaft and turn as a unit.

b. The energy of the vehicle is absorbed by the spinning of the rotor within an enclosed housing containing fluid (60 percent ethylene glycol/40 percent water). Welded to the top and bottom housing plates are stator blades (eight on each plate). These blades control the direction of flow of the absorber fluid which is set in motion by rotation of the rotor.

2. Retraction-System Operation: A follower attached to the upper tape-reel flange bears up against a spring-loaded cam, mating the retraction system to the purchase-tape reel. The spring-loaded cam is mounted to a sprocket and connected, through a drive chain, to a 10:1 speed reducer which is driven by a 37-horsepower Wisconsin air-cooled gasoline engine. The mating of the cam to the tape reel also serves as the pre-tensioning device capable of holding 1,500 to 2,000 pounds of pre-tension on the system. The cam is disengaged when the purchase-tape tension is increased to approximately 5,500 pounds.

3. Pressure Roller: During retraction, a roller is activated to obtain a tight wrap of the tape on the reels. By means of a winch--when the tape reel is empty--a 1,000-pound load is applied to the roller arm. This load forces the roller against the tape and presses the tape to the stack.

4. Mounting: The arresting gear was mounted on concrete mounting pads.

5. Configuration

a. Deck-sheave span - 225 feet

b. Reel-to-deck-sheave split - 17 feet

c. Uncoated nylon purchase tape - 920 feet long x 8 inches wide x 0.35 inch thick

d. Pendant

(1) Standard steel - 190 feet long x 1-1/4 inches in diameter NRWR

(2) Stainless-steel - 170 feet long x 1-1/4 inches in diameter

(3) Nylon - 175 feet long x 6-1/2 inches in circumference

e. Tensiometers

f. Pressure rollers

B. Pendants

1. The low-modulus nylon pendants were all constructed of Samson "2-in-1" braided nylon rope. The following coatings were used by the different manufacturers:

Manufacturer	Coating
AAE (All American Engineering Co.)	Neoprene coating GACO No. 700-A7
Goodyear Tire and Rubber Co.	Polyurethane Elastomer, Goodyear Code M-837-C
E. W. Bliss Co.	Polyurethane mixture consisting of equal parts by weight of Du Pont adiprene L-167 and L-213

2. The energy-absorbing stainless-steel pendant was manufactured by the ACCO (American Chain and Cable Company).

C. Connectors

1. Aluminum pendant-to-purchase-tape connector

2. Steel pendant-to-purchase-tape connector

3. Poured plastic terminal

D. Deadload Configuration for Simulated Aircraft Main-Wheel-Rim Rollover Tests: A deadload wheel rim was mounted beneath a Type II deadload, and was located in such a manner that the vertical static load on the wheel was approximately 12,000 pounds.

III TEST PROCEDURE

A. Procedure: Arrestments of a 25,000-pound deadload were conducted at RSTS (Recovery Systems Track Site) No. 5. The engaging speeds started at 114 knots and were increased in increments of approximately 10 knots to 233 and 165 knots for the ON- and OFF-CENTER tests respectively. The simulated aircraft main-wheel-rim rollover tests were conducted at approximately 100 knots.

B. Instrumentation: The parameters and methods of measuring were as follows:

Parameter Measured	Recording Method	Accurate Within (±)
Deadload longitudinal deceleration	Accelerometer	5%
Arresting-hook axial load	Strain gage	5%
Purchase-tape tension	" "	5%
Main-wheel-rim (used for rollover tests) vertical load	" "	5%
Engaging speed	Deck coils	2 Kn
Final position of slack cable	Painted deck marker	-

These measurements were either recorded on magnetic tape, displayed on oscillograms, or visually observed.

C. Test Limits: The following test limits were established for the test program:

Parameter	Test Limits
Engaging speed	240 Kn
Purchase-tape tension	65,000 Lb
Stainless-steel pendant tension	60,000 Lb
Deadload longitudinal deceleration	6 G
Arresting-hook axial load	191,000 Lb
Main-wheel-rim vertical load	100,000 Lb

D. Pendant Replacement Criteria: Pendants were to be replaced when one of the following occurred:

1. Standard Steel Pendant

   a. A total of nine broken wires

   b. Five or more broken wires per lay length

   c. The hemp core is visible

   d. The strands separate

   e. Kinks in the wire

2. Stainless-Steel Pendant

a. Three or more broken wires per lay length

b. The strands separate

c. The presence of 20 or more flat spots of 1/2 inch or more in length within one strand for one cable pitch length

d. Kinks in the wire

e. The inner core is visible

3. Nylon Pendant

a. The outer weave fails

b. Any damage to the spliced eyes

c. Cuts in the outer weave

d. Frayed nylon in the hook impact area

e. Any damage to the outer weave that might result in imminent failure of the pendant

f. Excessive abrasion along the length of the pendant

g. Cracking of the plastic filler in the poured terminal (applies only to pendant with poured plastic terminal)

IV TEST RESULTS AND DISCUSSION

A. Tests of Low-Modulus Nylon and Energy-Absorbing Stainless-Steel Deck Pendants

1. Base-Line Data

a. Testing began on 24 August 1970 with ON-CENTER arrestments of the 25,000-pound deadload. This phase required that a standard E-28 arresting-gear system be used (that is, one configured with a standard steel deck pendant). The results of these tests showed that the arresting-hook axial load data was from 15 to 50 percent higher than that obtained during the production check-out of a standard E-28 arresting-gear system. To ascertain the cause of this apparent anomaly in the arresting-hook load data, various steps were taken.

(1) A thorough check of the instrumentation system showed no discrepancy existed, and a complete disassembly of the absorber unit ruled out any interference.

(2) As a further check, a set of BAK-13 arresting-gear purchase tapes was installed on the E-28 and several arrestments were conducted. The resultant data obtained during these tests, for all practical purposes, was identical to that obtained during the E-28 production check-out tests. It is therefore suspected that a change in tape modulus may be responsible for the change in performance of the E-28 arresting-gear system.

b. On 11 September 1970, E-28 purchase tapes were reinstalled and the standard steel pendant was centered 3 feet OFF-CENTER in battery position. The arresting-hook load data obtained during tests with this configuration was only 16 percent higher than that acquired during the E-28 production check-out tests.

c. Curves constructed from the base-line data obtained during the above tests (pendant centered ON-CENTER and 3 feet OFF-CENTER) are presented in Figures 1 through 4. For evaluation purposes, however, only the pendant centered 3-foot OFF-CENTER curve will be used.

2. Test Deck Pendants: One hundred sixty events were conducted with the test pendants batteried ON-CENTER. Twenty of the events, however, were non-project events that were conducted as check events when two new absorbers were installed after the starboard unit was badly damaged (see paragraph IVD for discussion of damage). The 20 check events are not included in the evaluation to determine the optimum pendant in terms of lowest impact hook loads, but are included within the following table (paragraph IVA2a).

a. The following table summarizes how many arrestments each pendant tested withstood and the reason for removal (tabulated data sheets are presented in Appendix A):

Pendant No.	Number of Arrests	Engaging-Speed Range (Kn)	Reason for Removal	Refer to Figure
		AAE NYLON PENDANTS		
1	11	129 - 171	Abrasion	5
2	3	181 - 182	Spliced eye damaged by steel pendant connector	6
3	7	171 - 206	Nylon frayed in hook impact area	5
4	4	201 - 214	Abrasion	*
5	3	214 - 223	Outer weave of pendant separated; inner weave held for arrestment	5 & 7
6	2	223 - 226	Abrasion	*
7	2	230 - 232	Abrasion	*
8†	6	135 - 160	Pendant still usable: program complete	*
		BLISS NYLON PENDANTS		
1	11	131 - 181	Abrasion	8
2	6	189 - 204	Outer weave damaged in hook impact area	8
3	4	207 - 219	Abrasion	*
4	1	233	Spliced eye damaged when port tape failed	*
5	3	226 - 231	Abrasion	*
6†	6	114 - 162	Pendant still usable: program complete	*
Poured Terminals‡	6	149 - 170	Pendant still usable: program complete	*

* No photographs available.
† Pendant used for OFF-CENTER tests.
‡ Pendant used for both ON- and OFF-CENTER tests (see paragraph IVC for discussion on poured terminals).

Pendant No.	Number of Arrests	Engaging-Speed Range (Kn)	Reason for Removal	Refer to Figure
		GOODYEAR NYLON PENDANTS		
1	15	135 - 191	Abrasion	9
2	4	132 - 192	Pendant cut by sharp edge on hook shank	9
3	6	190 - 204	Spliced eye damaged when port tape failed	*
4	5	197 - 205	Nylon frayed in hook impact area	*
5	10	197 - 206	Abrasion	9
6	4	207 - 218	Nylon frayed in hook impact area	*
7	1	228	Nylon frayed in hook impact area	9
8	1	228	Abrasion	*
9†	6	130 - 165	Pendant still usable: program complete	*
		ACCO STAINLESS-STEEL PENDANTS		
1	5	118 - 152	Excessive flats	*
2	7	135 - 167	Excessive flats	*
3	4	158 - 175	Excessive flats and broken wires	*
4	2	181 - 182	3 broken wires	*
5	1	189	3 broken wires	*
6	1	190	Pendant damaged when starboard tape failed	*
7	1	190	1 broken strand	*
8	2	203 - 207	4 broken wires	*
9	2	197 - 219	Excessive flats	*
10	2	216 - 224	Pendant damaged when port tape failed	*
11†	5	132 - 160	15 broken wires	*
12†	1	161	Pendant still usable: program complete	*

* No photographs available.
† Pendant used for OFF-CENTER tests.

The minimum requirement of the Air Force was that a pendant withstand only one arrestment. The above tabulation shows that the pendants are capable of being used for more than one arrestment.

b. ON-CENTER Tests

(1) The peak arresting-hook axial loads and purchase-tape tensions were substantially reduced with the use of low-modulus nylon and stainless-steel pendants (see Figures 1 through 4). The following is a summary of the percent reduction as compared to the base-line data (comparisons of data are made to only 200 knots because the standard steel pendant was tested to only 190 knots):

Engaging Speed (Kn)	Base-Line Data (Lb)	Percent Reduction			
		Nylon Pendants			Stainless-Steel Pendants
		AAE	Bliss	Goodyear	(ACCO)
		ARRESTING-HOOK AXIAL LOAD			
130	50,200	34.8	30.0	28.0	7.2
150	70,800	36.2	33.2	31.2	18.3
170	95,100	37.2	35.6	33.6	26.4
190	123,800	38.2	37.8	35.8	33.1
200	139,700	38.4	38.8	36.6	36.0
		PURCHASE-TAPE TENSION			
130	31,500	28.0	29.2	29.8	17.0
150	40,400	27.8	27.3	28.5	19.8
170	50,100	27.6	25.4	27.0	21.8
190	60,800	27.4	24.0	25.8	23.6
200	66,400	27.3	23.2	25.2	24.6

(2) All three types of nylon pendants showed a capability to successfully withstand arrestments of a 25,000-pound deadload at engaging speeds up to 230 knots. The stainless-steel pendant showed the capability to successfully arrest a 25,000-pound deadload at an engaging speed of 224 knots: at this speed, the 60,000-pound tension limit imposed on the pendant is reached (see Figure 4).

c. The OFF-CENTER tests were conducted 35 feet OFF-CENTER to port. This was accomplished by relocating the arresting system 35 feet OFF-CENTER to starboard.

(1) The arresting-hook axial loads obtained during the OFF-CENTER tests were approximately the same as those obtained during the ON-CENTER tests (see Figures 1 through 4).

(2) During the OFF-CENTER tests, the hook "wiped" approximately 10 to 15 feet along the pendant. Each type of nylon pendant was used for a total of six OFF-CENTER arrestments. Two additional OFF-CENTER events were conducted to test the Bliss pendant with the poured plastic terminals. Each pendant displayed no apparent damage other than some scuffing of the coating where the hook "wiped" along the pendant.

(3) After four OFF-CENTER arrestments, a stainless-steel pendant had to be replaced because 15 wires broke as a result of hook "wipe" along the pendant. A second pendant was still in good condition after two arrestments.

d. The nylon pendants are torque-free and so do not rotate during the arrestment, and thus do not twist the tape. The stainless-steel pendants, however, do rotate during the arrestment; as a result, the tapes were twisted and the pendant was excessively snarled following each arrestment (see Figure 10). Approximately one-half hour was needed to unsnarl the pendant and to untwist the tape so that the system could be retracted into battery position for the next arrestment.

B. Simulated Aircraft Main-Wheel-Rim Rollover Tests: Twelve rollover tests were conducted in order to determine the extent to which a pendant would be damaged by a main-wheel-rim rollover. The deadload was configured as described in paragraph IID, page 3. The following is a summary of the results of these events:

Pendant			Main-Wheel-Rim Rollover Speed (Kn)	Apparent Damage	Refer to Figure
Manufacturer	Type	No.			
	Standard Steel	1*	107	Strands flattened where contacted by rim	11
	"	1*	103	" " " "	"
	"	1*	98	" " " "	"
AAE	Nylon	3	101	Outer weave partially cut	12
"	"	4	101	" " " "	"
"	"	7	101	Outer weave completely cut	"
Bliss	"	2	100	Outer weave completely cut	13
"	"	5	102	Outer weave partially cut	"
"	"	6	98	Outer weave completely cut	"
ACCO	Stainless Steel	3	99	Strands flattened where contacted by rim	14
"	"	7	102	" " " "	"
"	"	11	102	" " " "	"

* Different section of pendant was used for each rollover.

If the pendant damage that was incurred during these tests had occurred during field use, immediate replacement of the nylon pendant would be necessary, and although advisable to replace the standard steel and stainless-steel pendants, it may be possible to use them for one additional arrestment.

C. Connectors

1. The E. W. Bliss Company supplied three low-modulus nylon deck pendants with poured plastic terminals for use with the standard E-28 tape connector (see Figure 15). Only one of these was used: six arrestments were conducted using this pendant.

a. It was the intention of the manufacturer that the terminals be free to rotate around the plastic filler, but during the first arrestment the plastic became wedged in the terminal and bound. This had no apparent effect on the performance of either the nylon pendant or the terminal.

b. After the sixth arrestment, inspection of the terminals revealed that they were in excellent condition with no apparent signs of cracking of the plastic.

2. Several types of pendant-to-purchase-tape connectors were used during the test program. Standard E-28 connectors were used with the following pendants: standard steel, stainless steel, and the Bliss nylon pendant with a poured plastic terminal. The remaining nylon pendants had eye splices which required a specially designed connector. Two types of connectors were tested: one made of steel and one made of aluminum.

a. Steel Connectors (see Figure 16): This type consisted of a steel frame and an aluminum pulley and was used in conjunction with the standard E-28 connector. Use of the steel connector had to be discontinued after 17 arrestments because its edge was damaging the eye splice of the pendant (see Figure 6).

b. Aluminum Connectors (see Figure 17): This type consisted of a wedge and a frame that connected directly to the purchase tape. Ninety-five arrestments were conducted using these connectors. One connector had to be replaced after 43 arrestments because it was damaged by the hook after a purchase tape had parted. Both the original connector and the replacement connector were in excellent condition at the completion of the test program (95 and 52 arrestments respectively).

D. Major Arresting-Gear Damage

1. During project event 119 (231 knots engaging speed), a broken weld in a segment of the false bottom of the starboard energy absorber caused major damage to the absorber (see Figure 18 and Appendix B). It is considered that the steel plate of the false bottom was bent upward due to the turbulence of the fluid during the arrestment. The damaged plate wedged itself between the stator and rotor vanes and forced the shaft upward against the energy absorber cover, bowing the cover 1/2 inch.

2. Two new absorbers were installed for the completion of the test program. Before resumption of the test program, 20 non-project arrestments using nylon pendants were conducted as check shots in order to assure that the data acquired using the new absorbers was similar to the data acquired using the original absorbers.

E. Purchase-Tape History: The following is a summary of the purchase tapes used for the test program:

Tape	No. of Events	Reason for Replacement
N-121	7	Tape damaged
N-91	41	Excessive edge wear
N-209	44	Tape parted
N-76	56	Abrasion and excessive edge wear
N-131	56	" " " " "
N-225	22	Tape parted
N-52	19	" "
BAK-13	46	Excessive edge wear
BAK-13	42	Tape parted when tape tucked
N-207	40	Still usable: program complete
N-223	30	" " " "

The total number of events on the tapes is more than the total number of project events: some of the tapes were used during the events that were conducted to determine the reason for the anomaly in the data at the beginning of the test program and to check the new absorbers.

V CONCLUSIONS

A. Nylon pendants substantially reduced peak arresting-hook loads and peak purchase-tape tensions. (Paragraph IVA2b)

B. Stainless-steel pendants also reduced peak arresting-hook loads and peak purchase-tape tensions, but to a lesser degree than the nylon pendants. (Paragraph IVA2b)

C. All nylon pendants tested have the capability to successfully withstand an arrestment of a 25,000-pound deadload at engaging speeds up to 230 knots. (Paragraph IVA2b)

D. Stainless-steel pendants have the capability to successfully withstand an arrestment of a 25,000-pound deadload at engaging speeds up to 224 knots. (Paragraph IVA2b)

E. The stainless-steel pendants are unsatisfactory due to the excessive twisting of tapes which occurs during the arrestment. (Paragraph IVA2d)

F. The arresting-gear performance obtained with all three types of nylon pendants was approximately the same. (Paragraph IVA2)

G. The nylon pendants were cut by each simulated aircraft main-wheel-rim rollover and were unsuitable for further use in the arresting system. The standard steel and the stainless-steel pendants, although damaged by the wheel rim, may be usable for one additional emergency arrestment. (Paragraph IVB)

H. The poured plastic terminals are considered to be satisfactory for arrestments at speeds up to 170 knots. (Paragraphs IVA2a and IVC)

I. The steel nylon-pendant-to-purchase-tape connector is considered to be unsatisfactory. (Paragraph IVC)

J. The aluminum nylon-pendant-to-purchase-tape connector is considered to be satisfactory and acceptable for use. (Paragraph IVC)

VI RECOMMENDATIONS

A. Because all arrestments conducted during the test program were with a 25,000-pound deadload and the E-28 arresting-gear system, and because the low-modulus nylon deck pendants exhibited the capability to successfully withstand more than one arrestment, tests should be conducted to:

1. Determine the performance of the low-modulus nylon pendants with various heavier-weight deadloads using the E-28 arresting gear.

2. Determine aircraft arresting-hook-point compatibility and aircraft performance with low-modulus nylon pendants.

3. Determine the performance of the low-modulus nylon pendants with various arresting systems.

4. Determine life and replacement criteria of the low-modulus nylon pendants.

B. Data obtained during tests with the E-28 arresting-gear system should not be extrapolated for other arresting systems.

C. Low-modulus nylon pendants should be considered as a replacement for standard steel pendants for use in high-speed arrestments provided the above-mentioned tests are conducted and prove to be successful.

D. Stainless-steel pendants should not be considered as a replacement for standard steel pendants because of the excessive twisting of the tapes that occurs during the arrestment.

E. Based on the results of this limited test program, any of the three types of nylon pendants can be selected for use by the Air Force.

F. Additional tests should be conducted to:

1. Determine the capability of the poured plastic terminal at engaging speeds up to 230 knots.

2. Determine if standard steel and stainless-steel pendants that have been damaged by a main-wheel-rim rollover are capable of withstanding an additional emergency arrestment.

3. Determine nylon-pendant heights caused by nosewheel rollovers of aircraft-tire-section, donut, and plastic-rail pendant supports.

VII REFERENCE

(a) NAVAIRSYSCOM ltr AIR-5373B/21:JBO of 25 Feb 1970: Military Interdepartmental Purchase Request; acceptance of

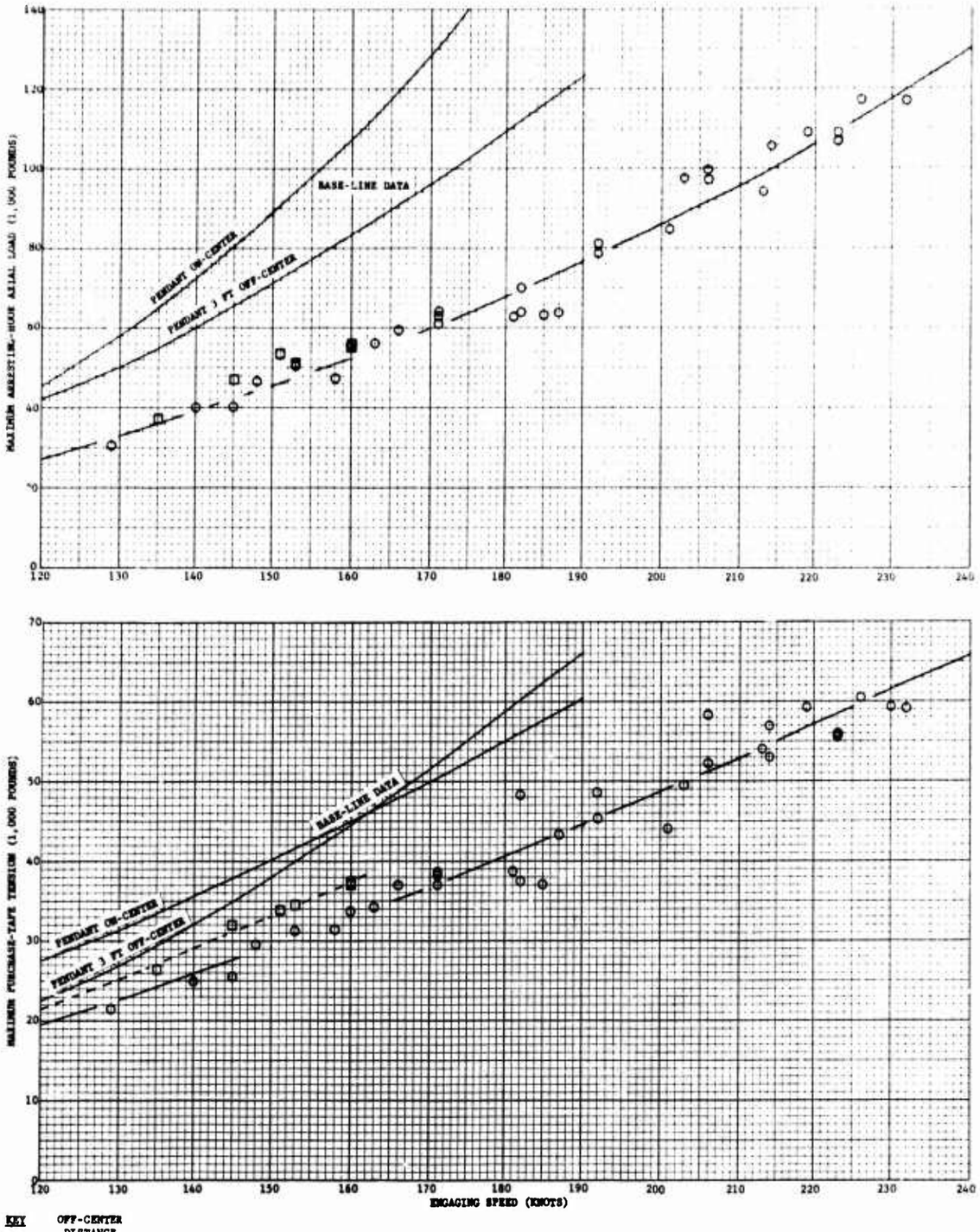


Figure 1 - ON-CENTER and 35-Foot OFF-CENTER to Port Arrestments of a 25,000-Pound Deadload Using All American Engineering Company Low-Modulus Nylon Deck Pendants (E-28 Arresting-Gear System Configured on a 225-Foot Deck Span)

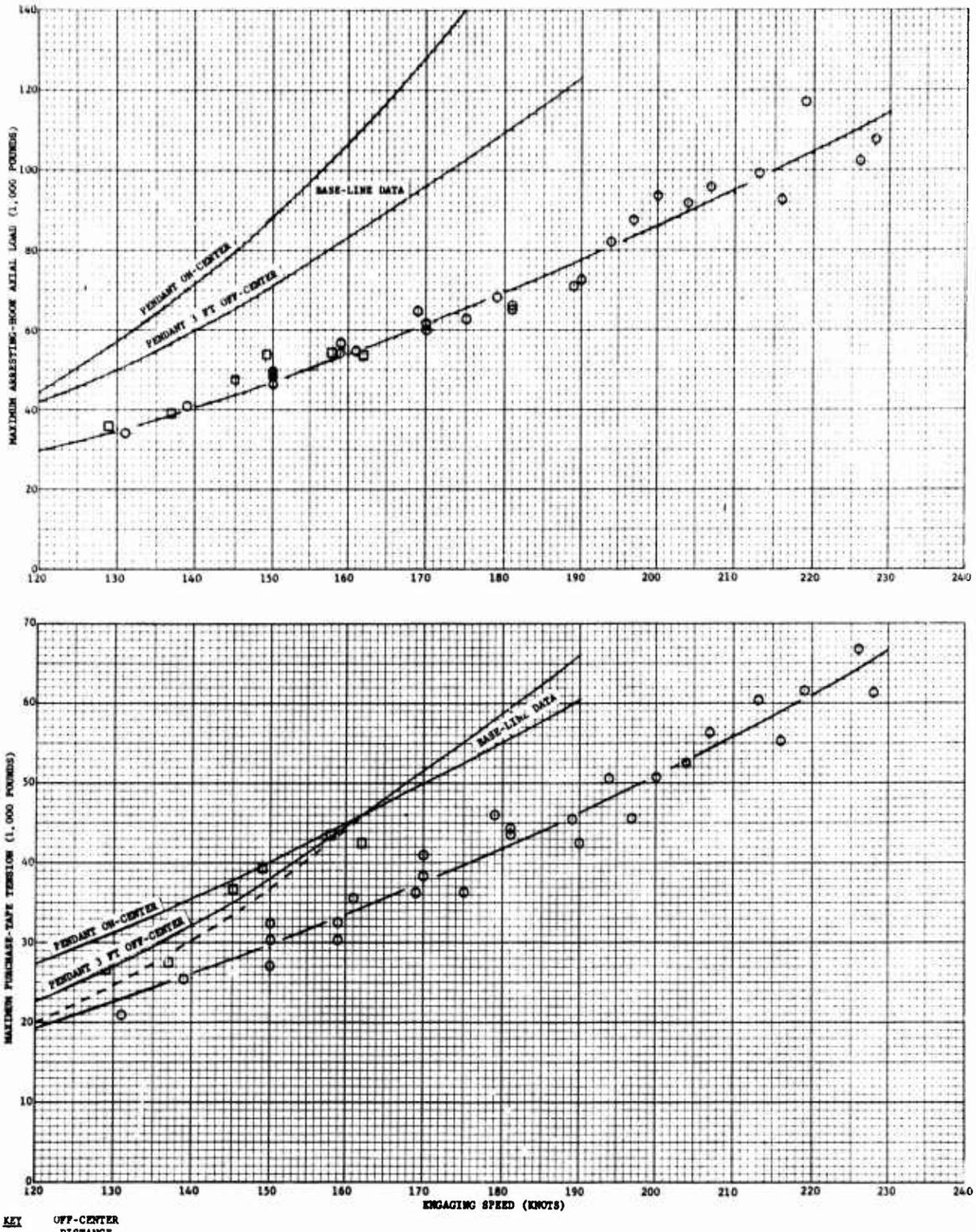


Figure 2 - ON-CENTER and 35-Foot OFF-CENTER to Port Arrestments of a 25,000-Pound Deadload
Using E. W. Bliss Company Low-Modulus Nylon Deck Pendants
(E-28 Arresting-Gear System Configured on a 225-Foot Deck Span)

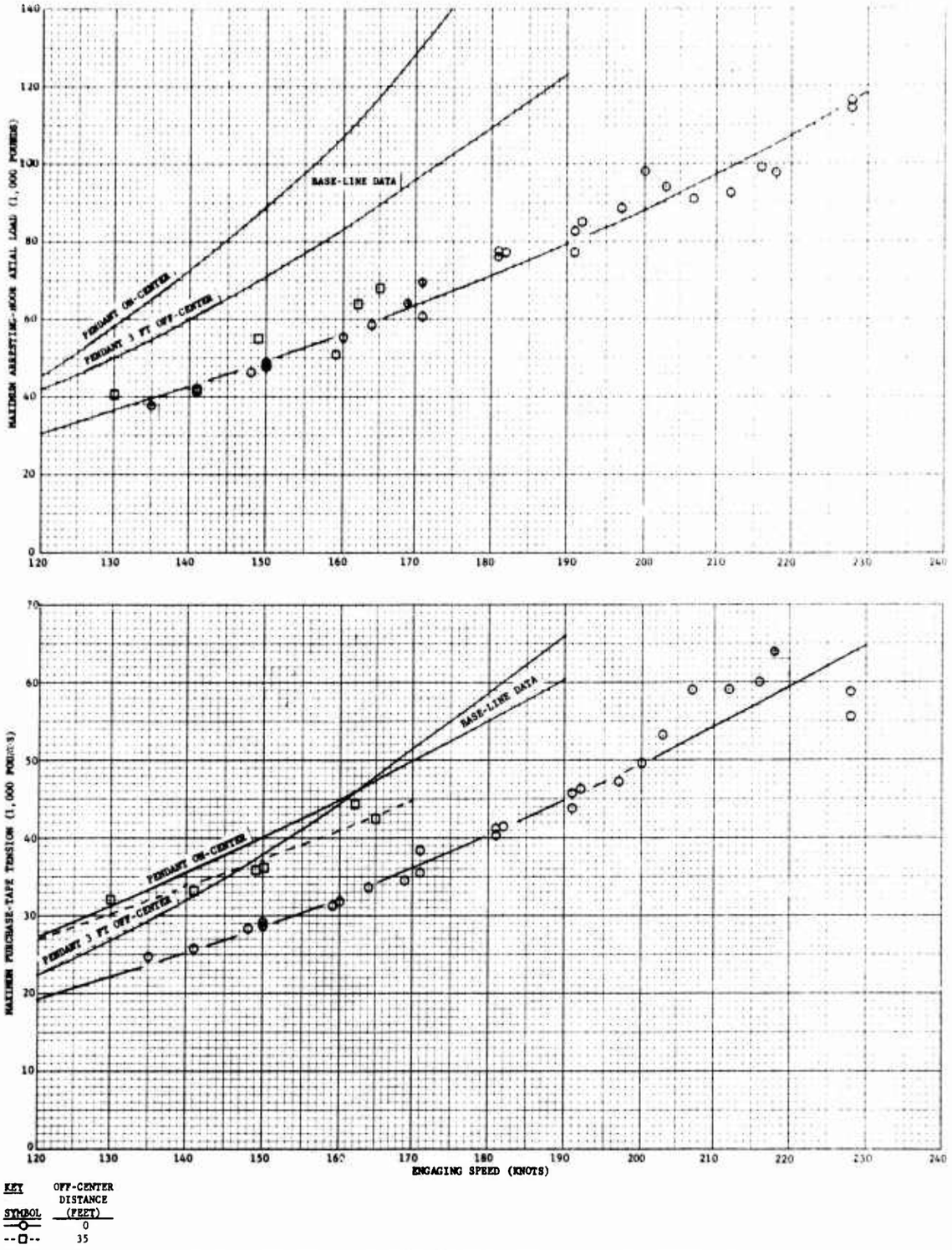
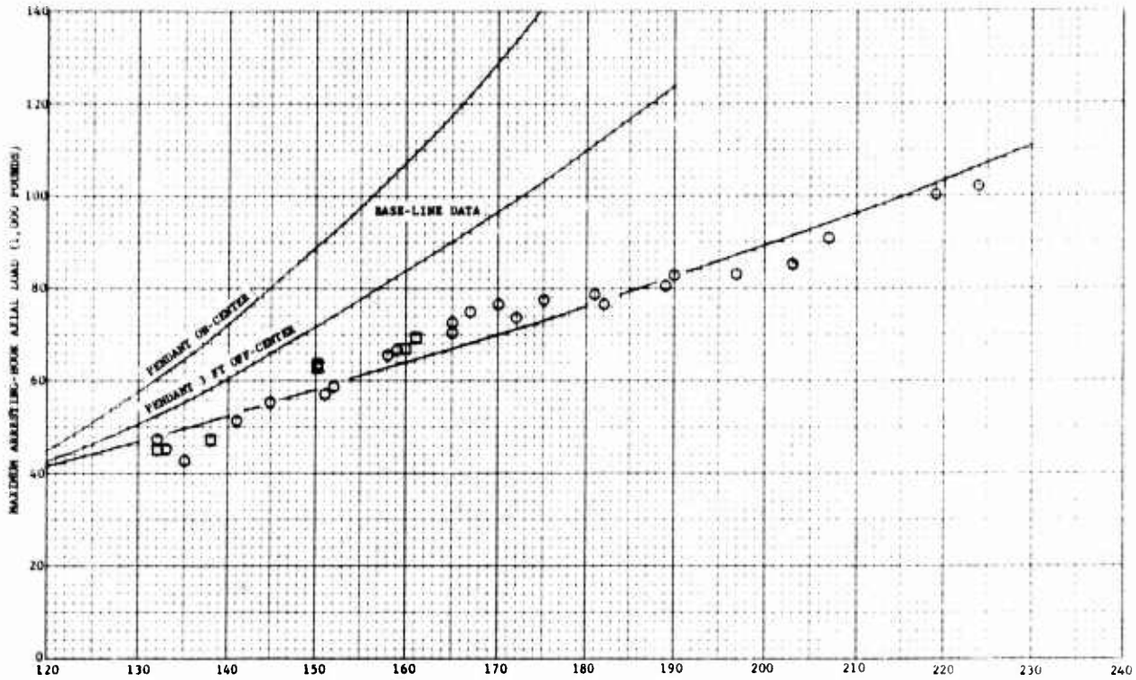
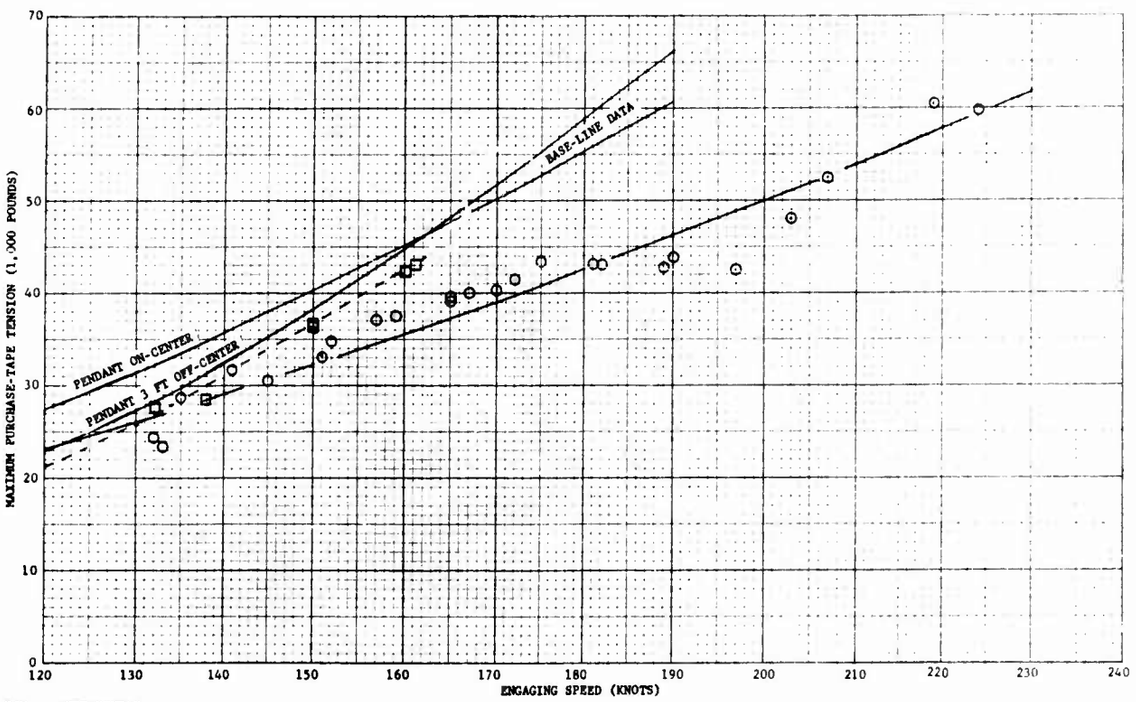


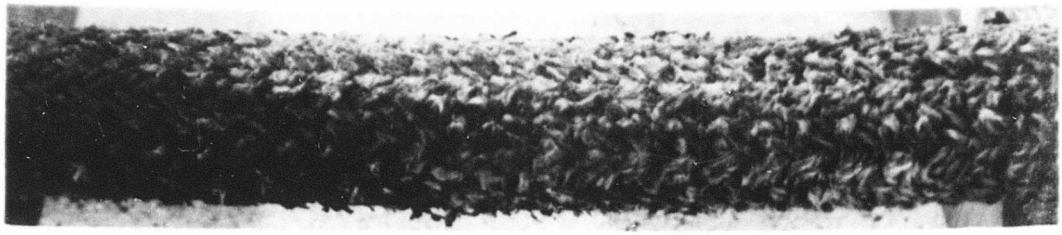
Figure 3 - ON-CENTER and 35-Foot OFF-CENTER to Port Arrestments of a 25,000-Pound Deadload Using Goodyear Tire and Rubber Company Low-Modulus Nylon Deck Pendants (E-28 Arresting-Gear System Configured on a 225-Foot Deck Span)



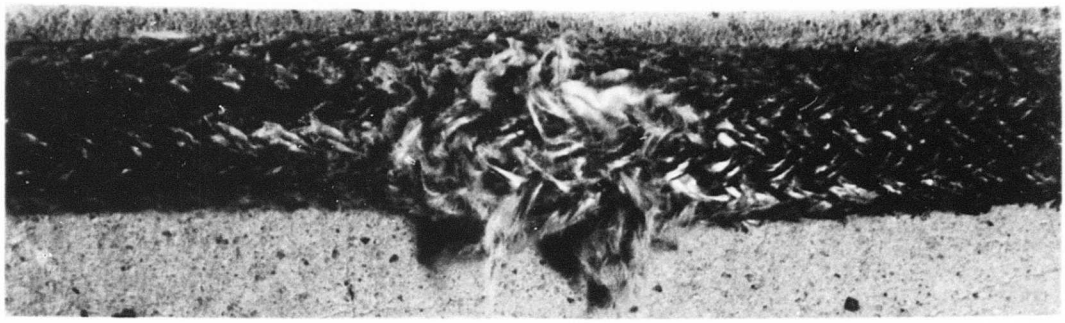


KEY SYMBOL	OFF-CENTER DISTANCE (FEET)
—○—	0
--□--	35

Figure 4 - ON-CENTER and 35-Foot OFF-CENTER to Port Arrestments of a 25,000-Pound Deadload Using American Chain and Cable Company Energy-Absorbing Stainless-Steel Deck Pendants (E-28 Arresting-Gear System Configured on a 225-Foot Deck Span)



AAE PENDANT NO. 1 FOLLOWING 11 ARRESTMENTS AT 129 TO 171 KNOTS



AAE PENDANT NO. 3 FOLLOWING 7 ARRESTMENTS AT 171 TO 206 KNOTS

AAE PENDANT NO. 5 FOLLOWING 3 ARRESTMENTS AT 214, 219, AND 223 KNOTS
(ALSO SEE FIGURE 7)

Figure 5 - All American Engineering Company Low-Modulus Nylon Deck Pendant (25,000-Pound Deadload, E-28 Arresting-Gear System)

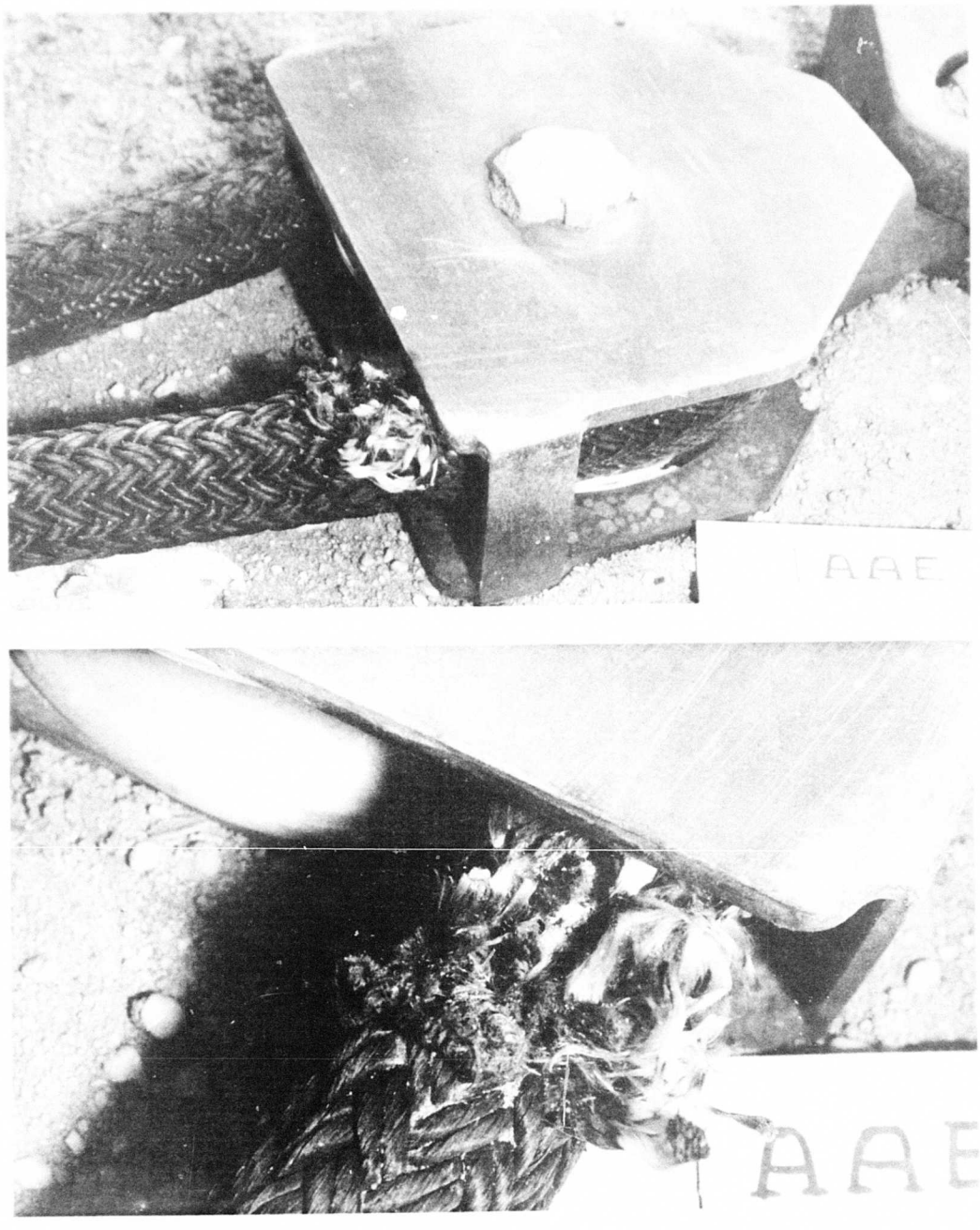


Figure 6 - All American Engineering Company Low-Modulus Nylon Deck Pendant No. 2 Following 3 Arrestments at 181, 182, and 182 Knots (25,000-Pound Deadload, E-28 Arresting-Gear System)

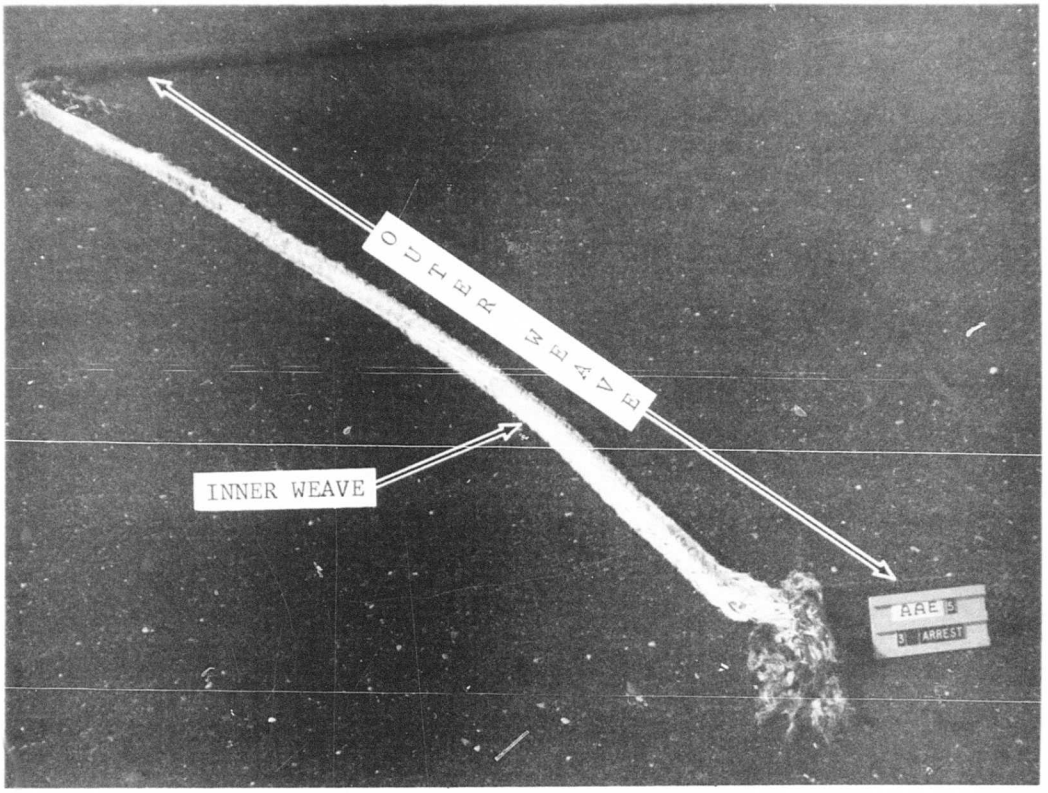
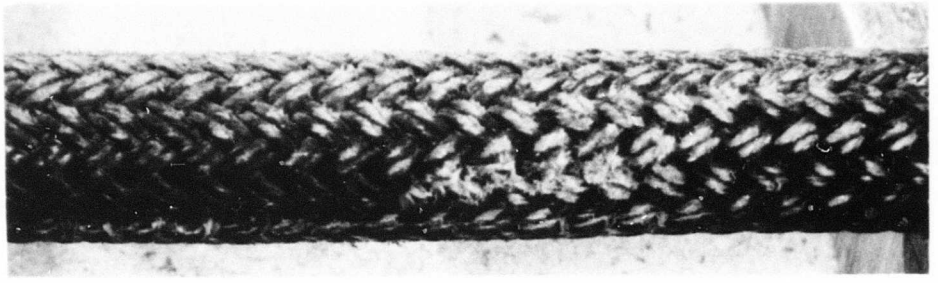
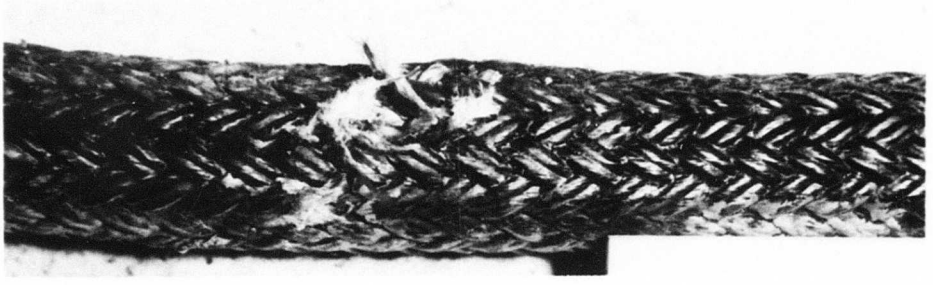


Figure 7 - View of All American Engineering Company Low-Modulus Nylon Deck Pendant No. 5 Following 3 Arrestments at 214, 219, and 223 Knots: Outer Weave Failed at 223 Knots but Inner Weave Held for Arrestment (25,000-Pound Deadload, E-28 Arresting-Gear System)

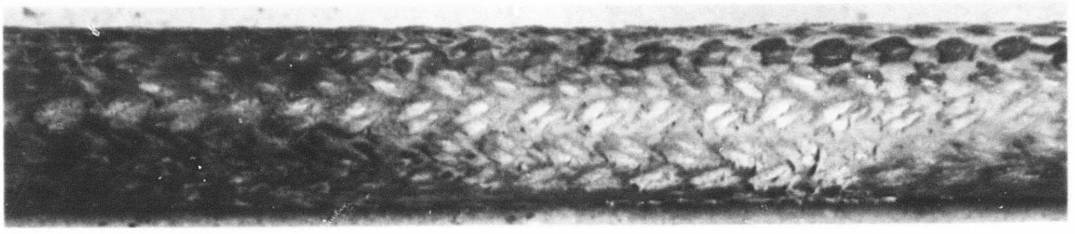


BLISS PENDANT NO. 1 FOLLOWING 11 ARRESTMENTS AT 131 TO 181 KNOTS

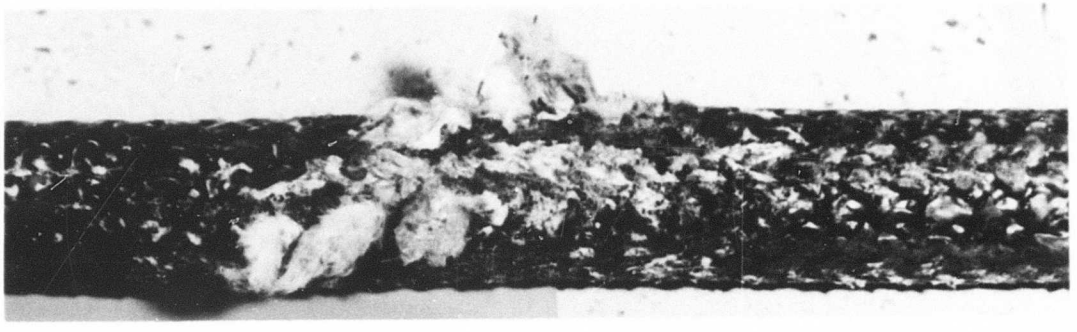


BLISS PENDANT NO. 2 FOLLOWING 6 ARRESTMENTS AT 189 TO 204 KNOTS

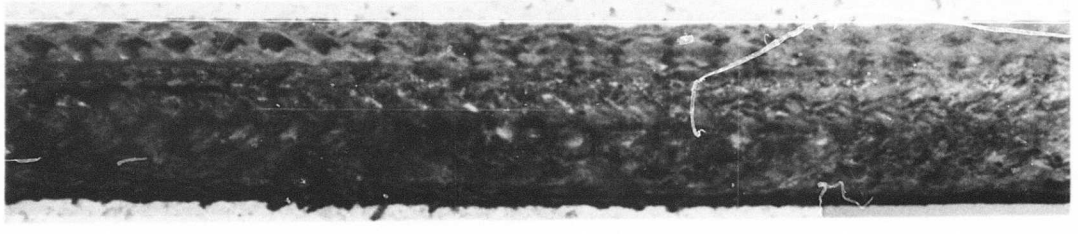
Figure 8 - E. W. Bliss Company Low-Modulus Nylon Deck Pendant (25,000-Pound Deadload, E-28 Arresting-Gear System)



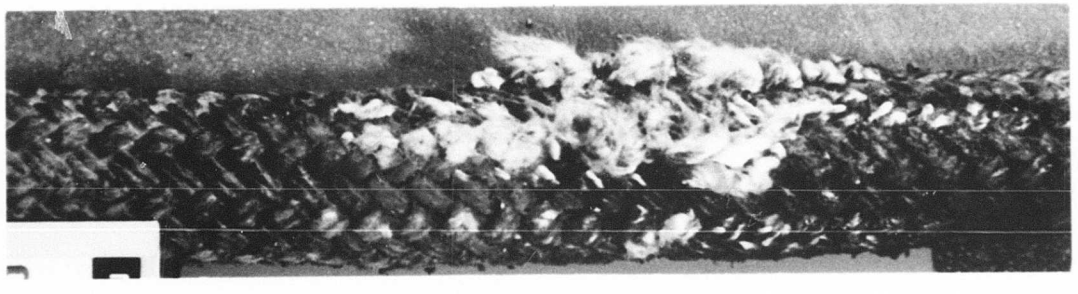
GOODYEAR PENDANT NO. 1 FOLLOWING 15 ARRESTMENTS AT 135 TO 191 KNOTS



GOODYEAR PENDANT NO. 2 FOLLOWING 4 ARRESTMENTS AT 132 TO 192 KNOTS

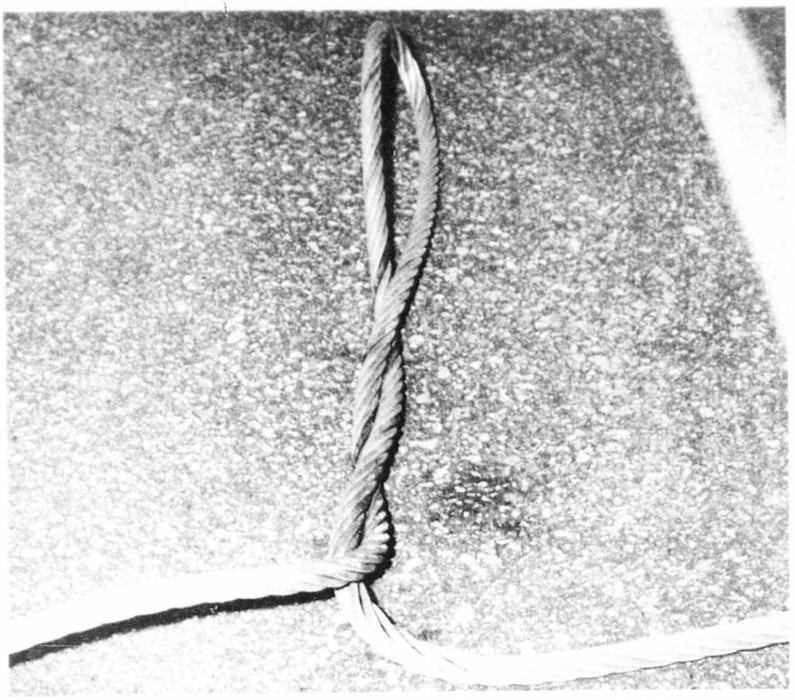


GOODYEAR PENDANT NO. 5 FOLLOWING 10 ARRESTMENTS AT 197 TO 206 KNOTS



GOODYEAR PENDANT NO. 7 FOLLOWING 1 ARRESTMENT AT 228 KNOTS

Figure 9 - Goodyear Tire and Rubber Company Low-Modulus Nylon Deck Pendant (25,000-Pound Deadload, E-28 Arresting-Gear System)



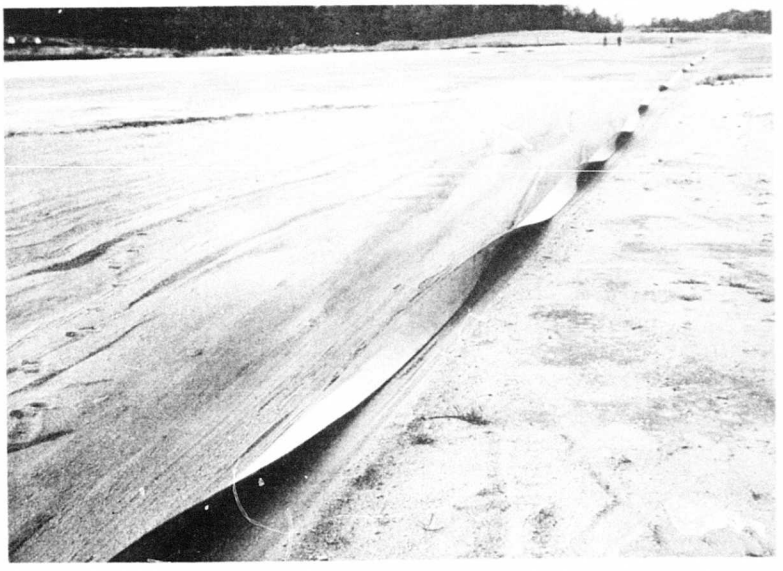


Figure 10 - Snarled American Chain and Cable Company Energy-Absorbing Stainless-Steel Deck Pendant and Twisted Purchase Tape Following Arrestment (25,000-Pound Deadload, E-28 Arresting-Gear System)

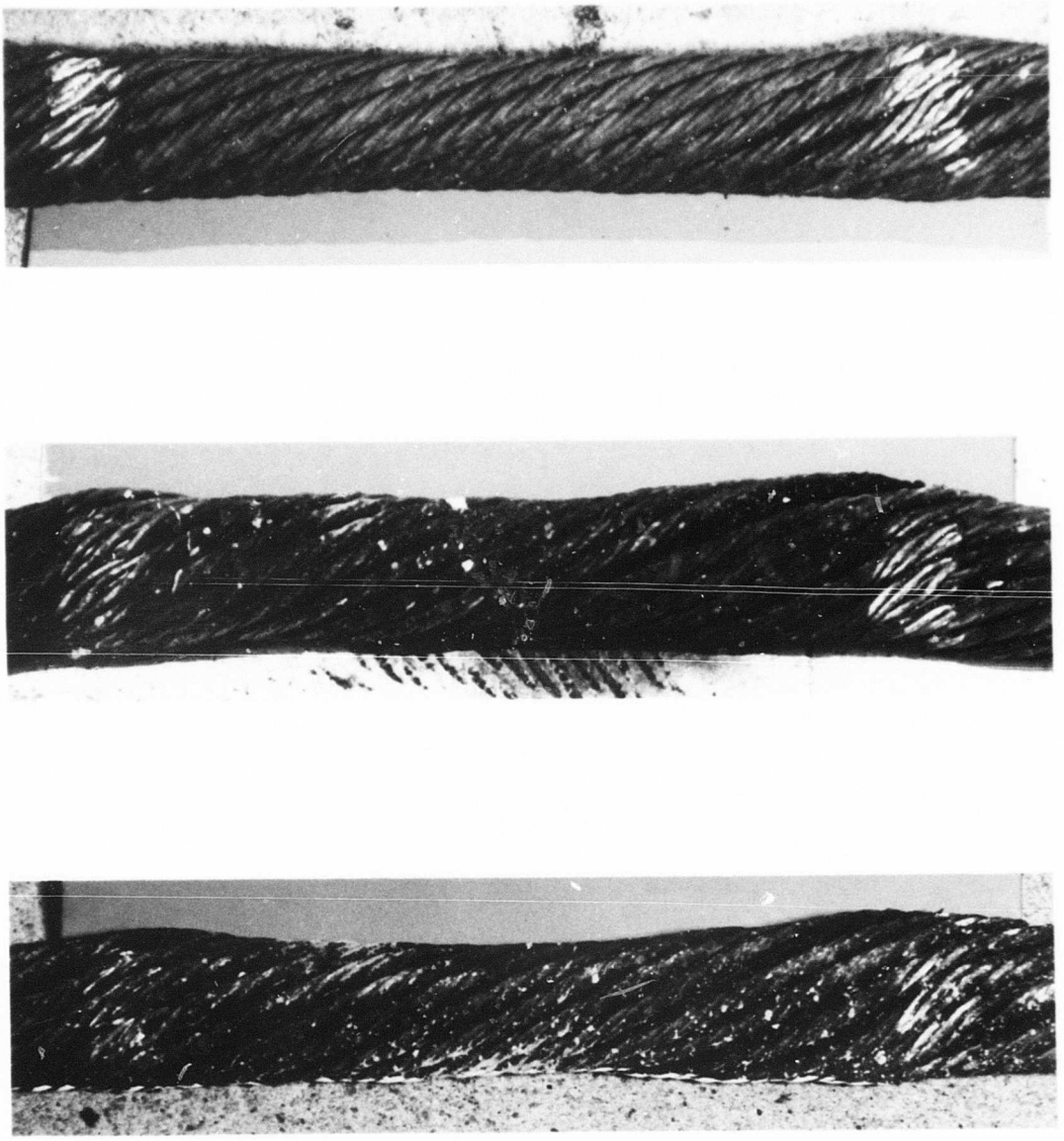


Figure 11 - Results of Simulated Aircraft Main-Wheel-Rim Rollovers of Standard Steel Deck Pendant No. 1 at Speeds of 107, 103, and 98 Knots Respectively (Different Section of Pendant Used for Each Rollover)

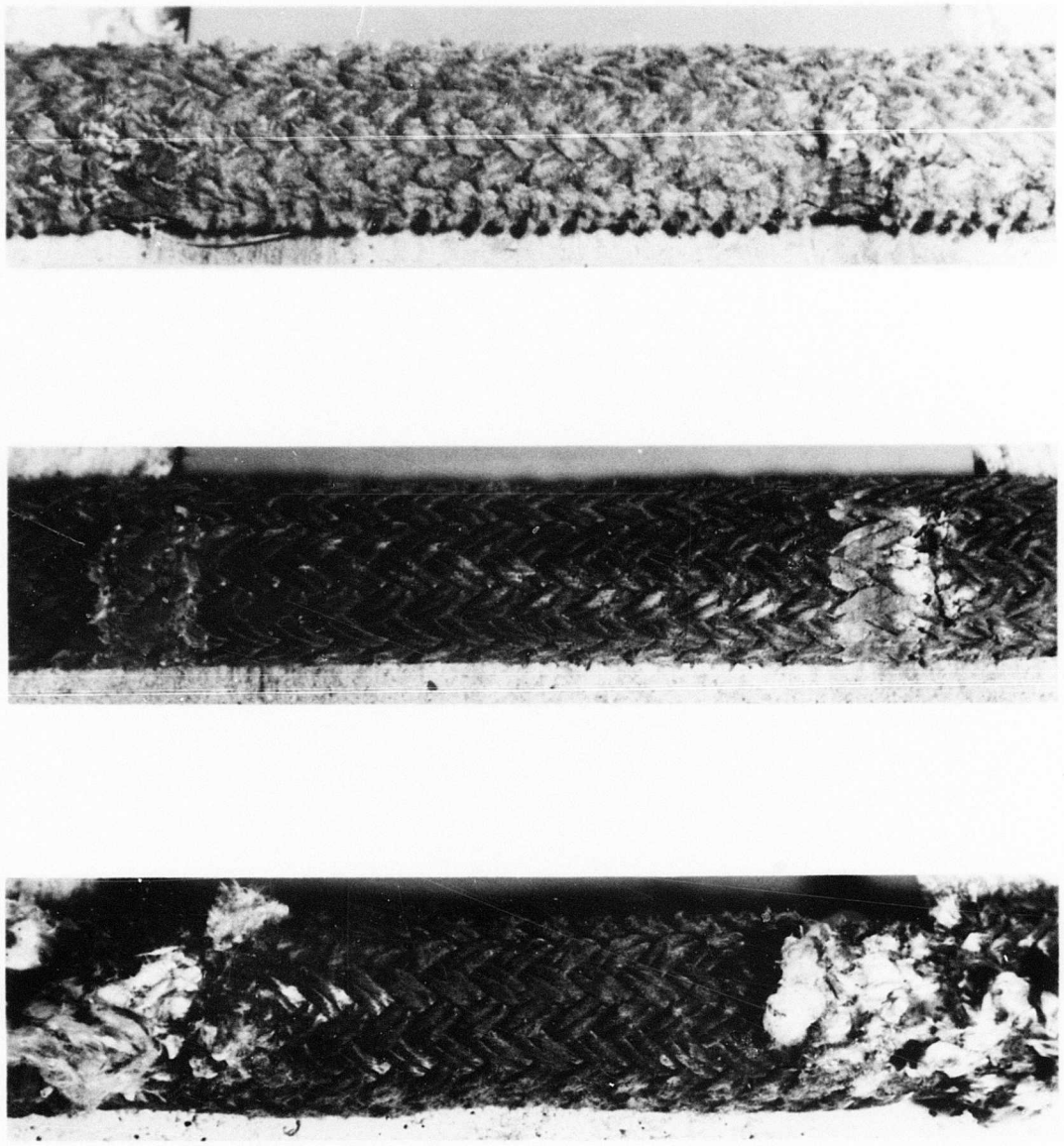


Figure 12 - Results of Simulated Aircraft Main-Wheel-Rim Rollovers of All American Engineering Company Low-Modulus Nylon Deck Pendants No. 3, 4, and 7, Respectively, at a Speed of 101 Knots

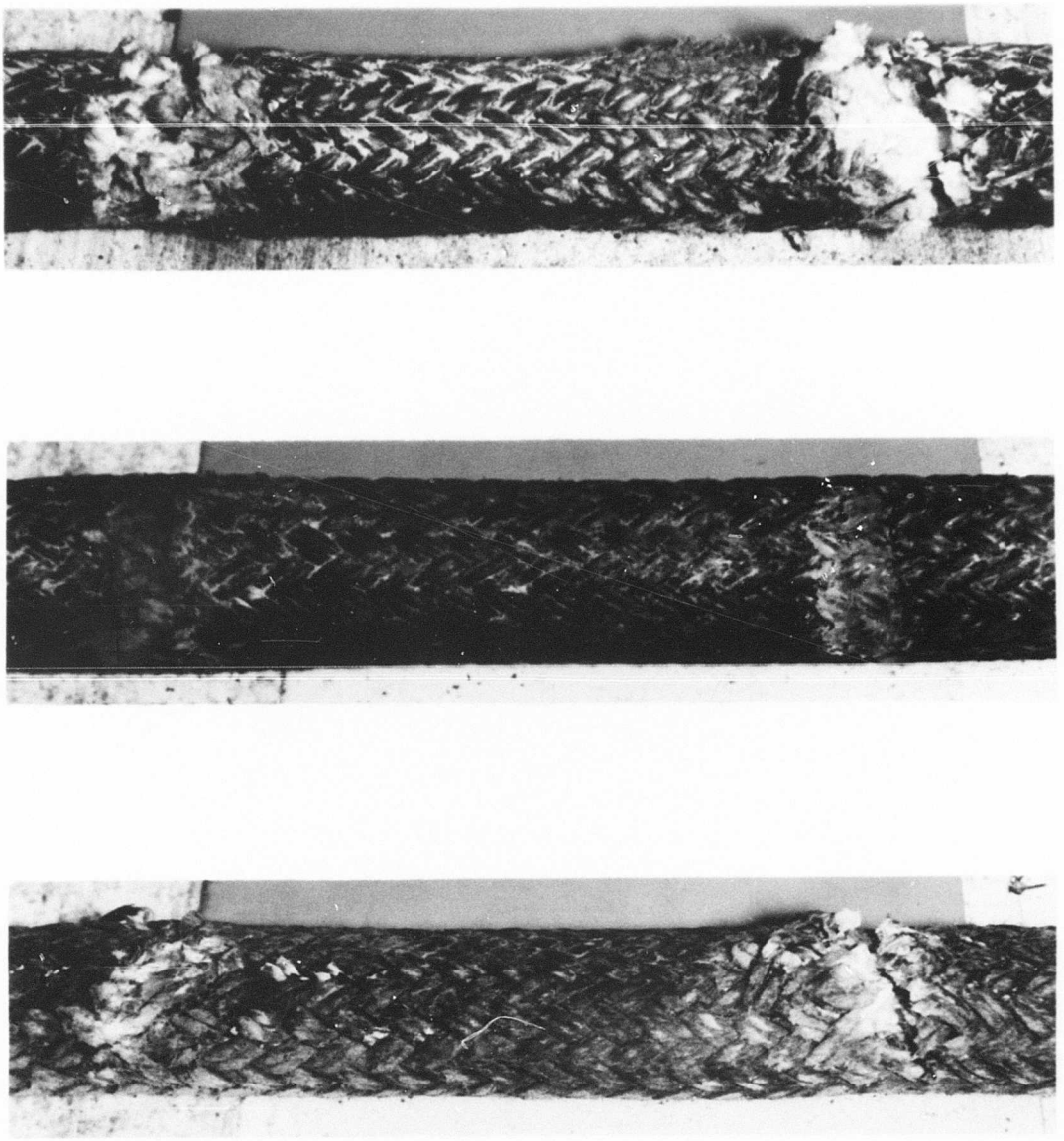


Figure 13 - Results of Simulated Aircraft Main-Wheel-Rim Rollovers of E. W. Bliss Company Low-Modulus Nylon Deck Pendants No. 2, 5, and 6 at Speeds of 100, 102, and 98 Knots Respectively

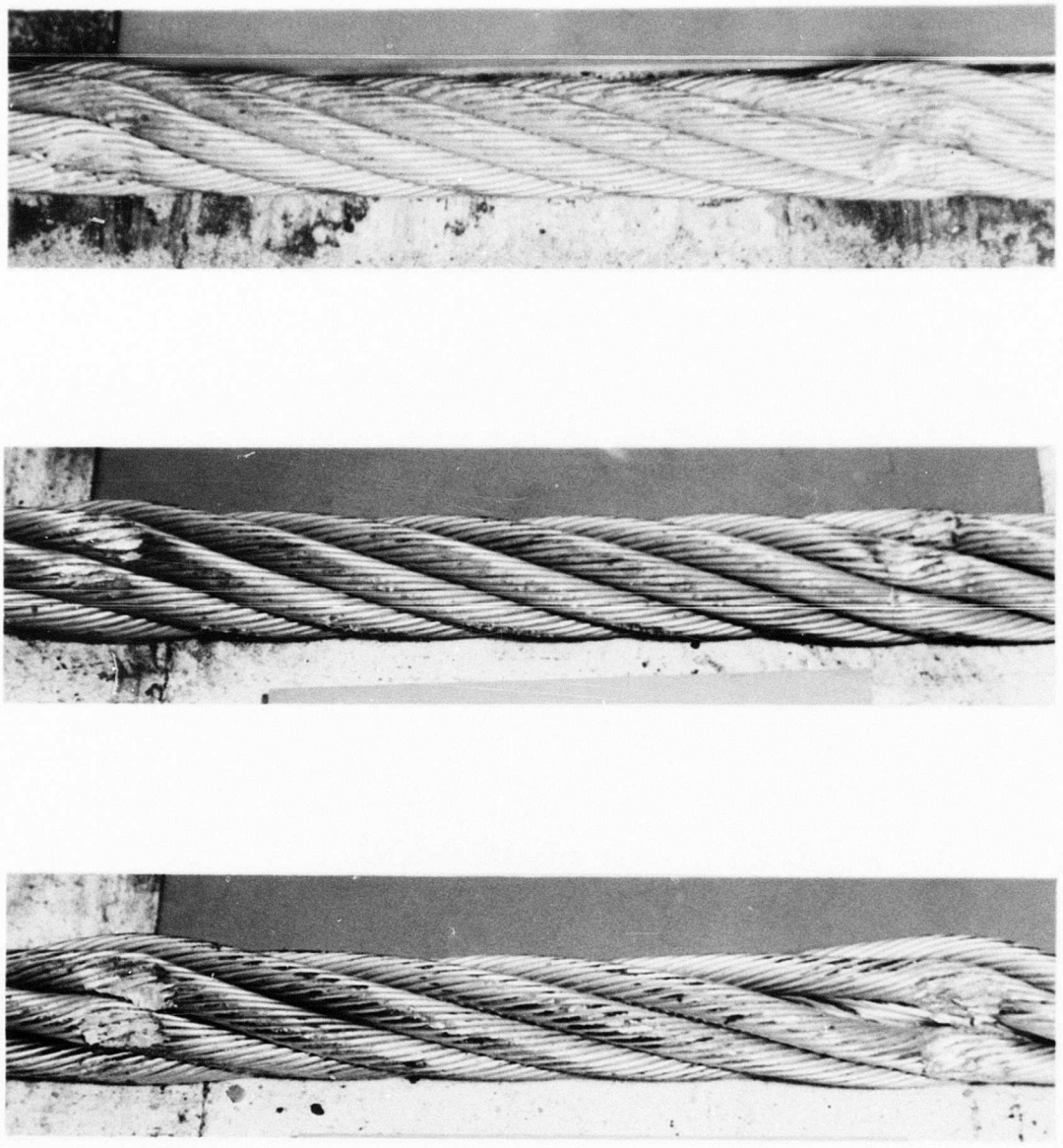


Figure 14 - Results of Simulated Aircraft Main-Wheel-Rim Rollovers of American Chain and Cable Company Energy-Absorbing Stainless-Steel Deck Pendants No. 3, 7, and 11 at Speeds of 99, 102, and 102 Knots Respectively

Figure 15 - E. W. Bliss Company Low-Modulus Nylon Deck Pendant With Poured Plastic Terminal for Use With Standard E-28 Tape Connectors

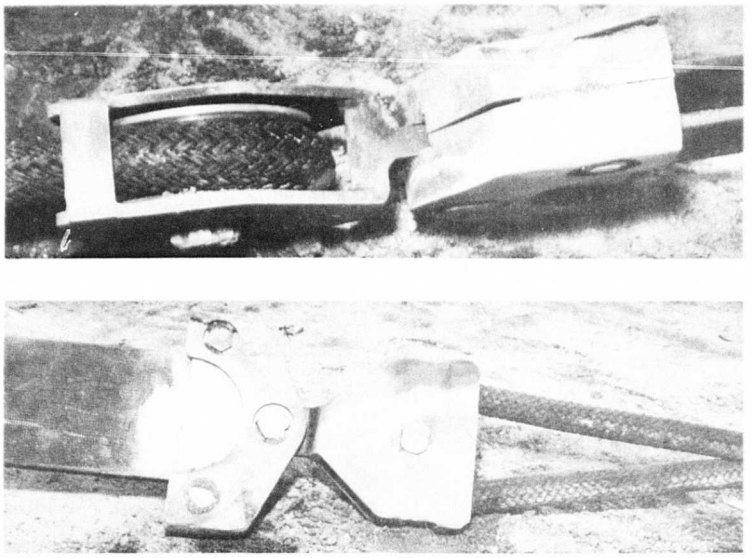


Figure 16 - Views of Steel Nylon-Pendant-to-Purchase-Tape Connector Used in Conjunction With the Standard E-28 Connector

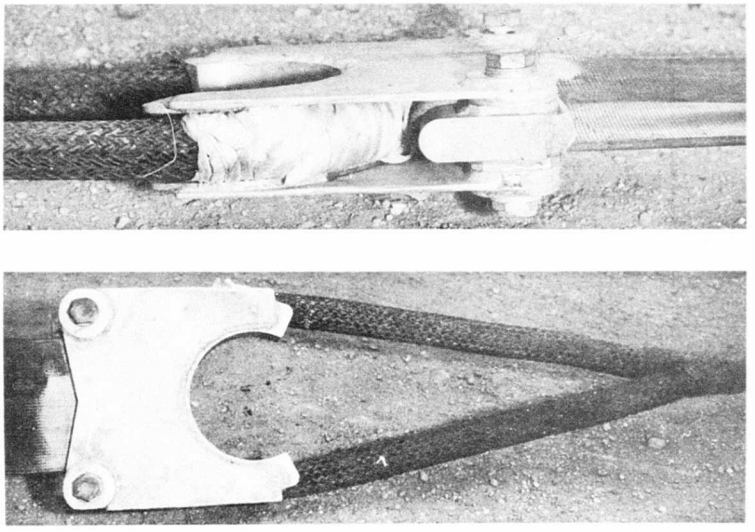


Figure 17 - Views of Aluminum Nylon-Pendant-to-Purchase-Tape Connector Consisting of a Wedge and a Frame That Connect Directly to the Purchase Tape

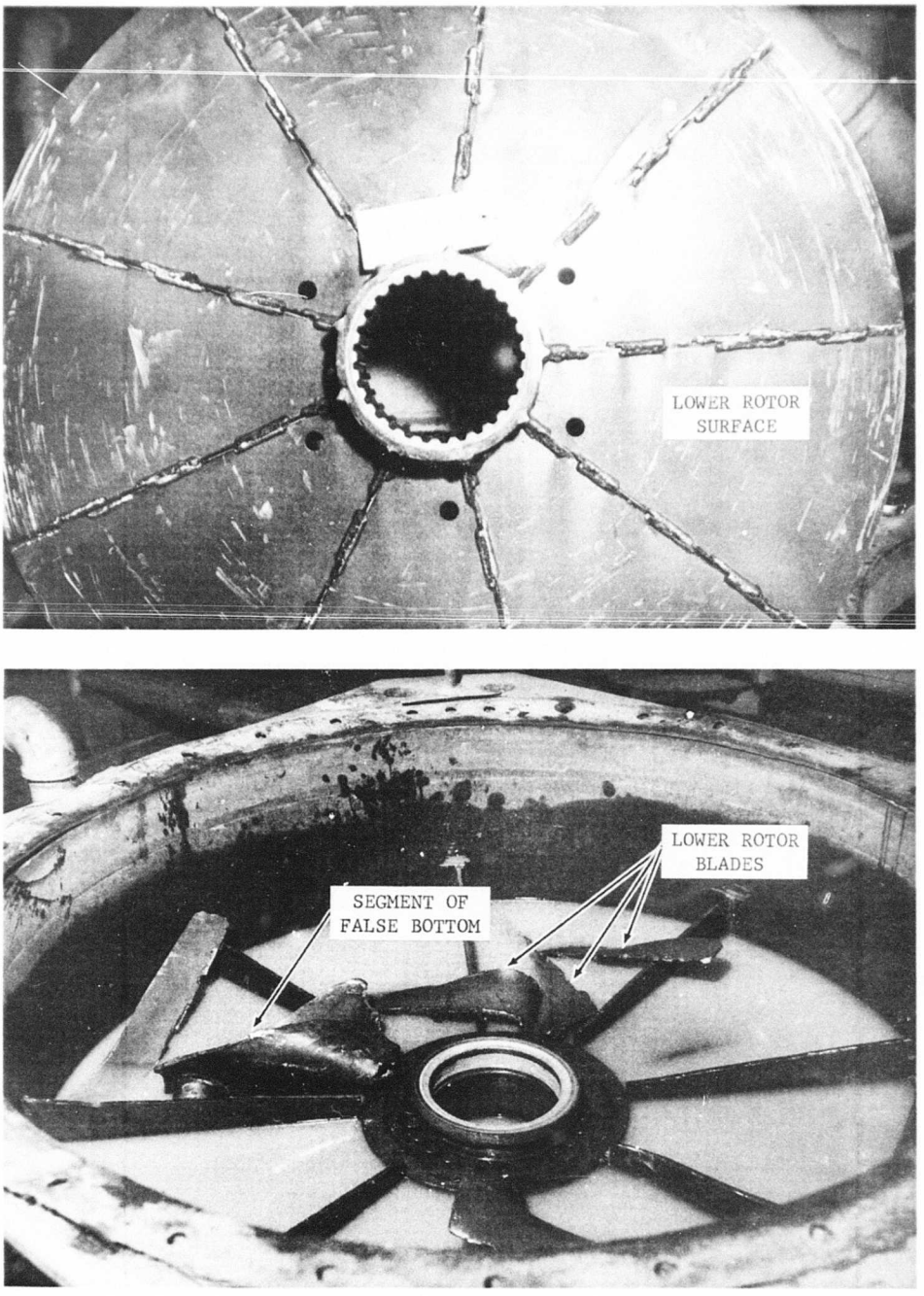


Figure 18 - Views of Starboard E-28 Absorber Showing Damage that Occurred During 231-Knot Arrestment of 25,000-Pound Deadload, Project Event 119

APPENDIX A - TABULATED DATA OF ARRESTMENTS OF A 25,000-POUND DEADLOAD (E-28 ARRESTING-GEAR SYSTEM)

Event No. Proj	Site	1970/1971 Date	Engaging Speed (Kn)	Maximum Arresting-Hook Axial Load (Lb)	Maximum Long. Decel (G)	Maximum Purchase-Tape Tension (Lb) Port	Maximum Purchase-Tape Tension (Lb) Stbd	Runout (Ft)	Pendant History No.	Pendant History No. of Events Used	Remarks
						STANDARD STEEL DECK PENDANT					
1	3,612	11 Sep	136	56,000	2.03	30,300	29,400	865	1*	14	
2	3,613	"	138	NV	NV	31,400	29,900	870		15	
3	3,620	29 Sep	140	61,300	2.16	33,700	34,100	880		22	
4	3,621	"	147	74,000	2.65	40,900	39,800	885		23	
5	3,622	"	150	73,200	2.70	39,700	39,000	885		24	
6	3,623	"	158	84,600	3.29	45,700	45,500	890		25	
7	3,624	30 Sep	132	46,400	1.96	27,400	27,600	875		26	
8	3,625	"	152	72,100	2.66	36,900	38,900	885		27	
9	3,626	"	162	85,400	3.04	44,600	45,300	895		28	
10	3,627	"	159	85,700	3.15	45,700	44,400	895		29	
11	3,628	"	169	91,400	3.58	49,500	50,800	900		30	
12	3,629	1 Oct	167	94,500	3.40	48,600	49,700	900		31	
13	3,630	"	168	85,200	3.19	45,600	42,800	900		32	
14	3,631	"	184	108,800	4.18	56,300	56,900	905		33	
15	3,632	"	179	108,600	4.08	56,900	56,700	905		34	5 broken wires in 1 lay length
16	3,644	14 Oct	179	111,100	3.81	47,200	58,800	905	2*	1	
17	3,645	"	185	109,800	4.28	58,800	57,100	905		2	
18	3,646	15 Oct	185	112,100	4.12	58,800	57,600	895		3	
19	3,649	19 Oct	187	116,800	4.31	NV	NV	895		6	
20	3,650	"	190	116,400	4.30	62,900	63,200	900		7	
21	3,651	20 Oct	186	113,200	4.23	60,100	59,900	910		8	
22	3,652	"	190	108,900	4.22	60,500	63,000	895		9	
23	3,653	"	190	121,200	4.48	61,200	62,500	895		10	Pendant still usable
						AAE LOW-MODULUS NYLON DECK PENDANTS ON-CENTER TESTS					
62	3,725	13 Jan	129	31,400	1.49	21,200	21,400	865	1	1	Steel connectors
63	3,726	"	140	40,100	1.78	24,900	23,800	875		2	
64	3,727	18 Jan	145	40,100	1.78	25,300	25,600	870		3	
65	3,728	"	148	46,800	1.37	28,400	29,700	880		4	
66	3,729	"	153	50,600	2.23	31,000	31,100	885		5	
67	3,730	"	160	55,600	2.50	31,800	33,900	885		6	
68	3,731	19 Jan	158	47,100	2.17	30,800	31,500	880		7	
69	3,732	"	163	55,900	2.48	32,900	34,200	885		8	
70	3,733	"	166	59,100	2.66	34,700	37,000	885		9	
71	3,734	"	171	62,700	2.70	36,300	38,200	890		10	
72	3,735	"	171	61,300	2.74	39,300	38,400	890		11	Pendant replaced due to abrasion
73	3,736	"	182	70,000	3.10	48,300	43,600	900	2	1	
74	3,737	20 Jan	181	62,400	2.94	38,200	38,800	900		2	
75	3,738	22 Jan	182	63,900	2.82	35,800	37,500	900		3	Pendant cut in loop area by cowbell
76	3,739	27 Jan	185	63,200	2.84	35,700	37,000	895	3	1	
77	3,740	"	187	63,800	2.86	43,200	41,700	895		2	
95	3,758	1 Feb	192	81,500	3.48	48,700	42,400	905		3	Aluminum connectors
96	3,759	"	171	63,100	2.66	36,900	36,200	885		4	
97	3,760	2 Feb	192	78,500	3.41	40,400	45,100	905		5	
99	3,768	9 Feb	203	97,500	3.58	48,900	49,500	900		6	
100	3,769	10 Feb	206	99,400	3.85	58,300	52,500	900		7	Pendant frayed in impact area
101	3,770	11 Feb	201	84,500	3.29	44,000	43,800	905	4	1	
102	3,771	"	206	97,100	3.75	48,000	52,300	905		2	
103	3,772	"	213	94,100	3.73	50,200	53,800	910		3	
104	3,773	12 Feb	214	NV	NV	51,600	53,000	915		4	Pendant replaced due to abrasion
105	3,774	"	219	109,900	4.30	54,900	59,200	920	5	1	
106	3,775	"	214	105,800	4.12	54,000	56,800	915		2	
107	3,776	17 Feb	223	106,300	4.12	52,700	55,600	920		3	Pendant outer weave broke inner weave held
108	3,777	19 Feb	226	117,300	4.60	55,400	60,800	920	6	1	
109	3,778	24 Feb	223	109,400	4.28	54,600	55,800	920		2	Pendant replaced due to abrasion
110	3,779	25 Feb	230	NV	NV	57,100	59,200	930	7	1	
131	3,828	28 Apr	232	117,200	4.79	58,800	58,700	930		2	Pendant replaced due to abrasion
						35-FOOT OFF-CENTER TO PORT TESTS					
146	3,844	20 May	135	37,000	1.79	26,400	21,400	850	8	1	
147	3,845	"	145	47,200	2.24	32,000	25,800	860		2	
148	3,846	"	153	51,000	2.56	33,600	34,700	865		3	
149	3,847	"	151	53,700	2.17	33,800	30,400	865		4	
150	3,848	"	160	55,800	2.55	37,300	36,500	880		5	
151	3,849	"	160	54,500	2.36	37,100	29,000	880		6	Pendant still usable

* Pendant centered 3 feet OFF-CENTER
NV = No value

Event No. Proj	Site	1970/1971 Date	Engaging Speed (Kn)	Maximum Arresting-Hook Axial Load (Lb)	Maximum Long. Decel (G)	Maximum Purchase-Tape Tension (Lb) Port	Stbd	Runout (Ft)	Pendant History No.	No. of Events Used	Remarks
					BLISS LOW-MODULUS NYLON DECK PENDANTS ON-CENTER TESTS						
45	3,701	10 Dec	131	34,300	1.49	19,900	21,000	855	1	1	Aluminum connectors
46	3,702	"	139	41,100	1.82	23,800	25,600	860		2	
47	3,703	"	150	48,400	2.13	32,500	29,300	875		3	
48	3,704	"	150	49,800	2.17	30,600	30,700	875		4	
49	3,705	"	161	54,400	2.38	35,700	33,200	880		5	
50	3,706	"	159	56,300	2.50	32,700	32,200	880		6	
51	3,707	11 Dec	175	62,800	2.74	36,400	36,400	890		7	
52	3,708	"	170	60,200	2.81	38,400	41,000	890		8	
53	3,709	"	179	68,200	2.86	43,400	46,000	890		9	
54	3,710	14 Dec	150	45,200	2.09	25,400	27,000	875	A	1	Poured plastic terminal pendant
55	3,711	15 Dec	159	54,300	2.26	30,300	28,400	880		2	
56	3,712	"	169	64,600	2.86	36,200	35,700	890		3	
57	3,713	"	170	61,900	2.67	34,200	38,300	890		4	
58	3,714	"	181	66,000	2.90	44,200	43,000	890	1	10	Pendant No. 1 reinstalled
59	3,715	"	181	65,600	2.88	43,700	41,400	890		11	Pendant replaced due to abrasion
60	3,723	21 Dec	189	70,700	2.99	40,500	45,500	900	2	1	Steel connectors
61	3,724	"	190	72,700	3.09	40,900	42,500	900		2	
98	3,761	2 Feb	194	82,600	3.47	50,900	47,900	910		3	Aluminum connectors
111	3,780	25 Feb	200	91,500	3.65	50,700	52,400	905		4	
112	3,781	"	197	87,600	3.46	45,400	45,100	900		5	
113	3,782	"	200	93,600	3.47	50,600	50,900	905		6	Outer weave damaged in impact area
114	3,783	"	213	99,200	3.82	53,200	60,100	910	3	1	
115	3,784	"	207	95,200	3.72	56,200	55,500	910		2	
116	3,785	26 Feb	219	117,200	4.22	58,900	61,700	920		3	
117	3,786	1 Mar	216	92,700	3.75	51,600	55,300	915		4	Pendant replaced due to abrasion
118	3,787	"	233	111,200*	3.79*	56,400*	53,800*	∞	4	1	Port tape failed; spliced eye damaged
119	3,788	5 Mar	232	112,100†	4.39†	66,100†	56,600†	980	5	1	Port & stbd absorber covers sprung,
129	3,826	27 Apr	226	102,300	3.92	57,600	66,900	930		2	stbd lower rotor blades torn off
130	3,827	"	228	106,900	4.10	56,600	61,100	930		3	Pendant replaced due to abrasion
					35-FOOT OFF-CENTER TO PORT TESTS						
139	3,836	14 May	137	39,600	1.69	27,800	,00	850	6	1	
140	3,838	"	114	29,800	1.14	21,400	18,000	830		3	
141	3,839	" May	129	35,400	1.46	26,800	21,400	845		4	
142	3,840	1[illegible] May	145	47,700	1.78	36,900	31,300	860		5	
143	3,841	"	162	53,800	2.17	30,200	42,600	880		6	Pendant still usable
144	3,842	"	149	53,800	2.21	39,600	39,000	860	A	5	Poured plastic terminal pendant re-
145	3,843	19 May	158	54,100	2.42	42,000	43,500	880		6	installed; pendant still usable
					GOODYEAR LOW-MODULUS NYLON DECK PENDANTS ON-CENTER TESTS						
78	3,741	27 Jan	148	46,200	2.03	26,200	28,300	865	1	1	Steel connectors
79	3,742	"	135	37,900	1.54	22,600	24,700	860		2	
80	3,743	28 Jan	141	42,200	1.74	24,200	25,900	865		3	
81	3,744	"	150	49,300	2.05	27,800	29,300	870		4	
82	3,745	"	150	48,500	2.01	27,300	28,900	870		5	
83	3,746	"	164	58,100	2.46	33,300	33,900	880		6	
84	3,747	"	160	55,700	2.23	30,300	31,900	875		7	
85	3,748	"	159	51,100	2.20	29,900	31,400	875		8	
86	3,749	"	171	60,800	2.55	34,400	35,700	885		9	
87	3,750	29 Jan	169	64,100	2.66	33,300	34,500	885		10	Aluminum connectors
88	3,751	"	171	69,600	2.93	33,200	38,200	885		11	
89	3,752	"	182	77,100	3.28	36,700	41,600	895		12	
90	3,753	"	181	76,200	3.22	37,900	41,300	895		13	
91	3,754	"	181	77,600	3.26	38,200	40,300	895		14	
92	3,755	"	191	81,500	3.38	41,000	43,900	905		15	Pendant replaced due to abrasion
93	3,756	1 Feb	191	77,100	3.38	43,600	45,800	905	2	1	
94	3,757	"	192	85,100	3.55	44,400	46,100	905		2	Sharp edge on hook shank cut pendant
120	3,804	15 Apr	203	94,300	3.78	52,400	53,400	900	3	5	
121	3,805	"	201	NV	NV	NV	NV	∞		6	Port tape broke; hook cut pendant loop
122	3,819	23 Apr	200	98,200	3.75	47,900	49,800	920	5	9	
123	3,820	"	197	88,500	3.48	43,600	47,100	920		10	Pendant replaced due to abrasion
124	3,821	"	207	91,000	3.58	48,100	59,000	925	6	1	
125	3,822	"	212	92,200	3.60	49,800	59,900	930		2	
126	3,823	"	216	98,900	3.83	56,900	60,000	930		3	
127	3,824	"	218	97,700	3.82	63,900	61,500	935		4	Pendant frayed in impact area
128	3,825	27 Apr	228	114,200	4.40	51,500	55,600	935	7	1	Pendant frayed in impact area
132	3,829	29 Apr	228	116,900	4.52	54,600	58,700	935	8	1	Pendant replaced due to abrasion

* Maximum loads occurred before failure.
† Not valid for evaluation purposes due to absorber failure.
NV = No value

Event No. Proj	Event No. Site	1970/1971 Date	Engaging Speed (Kn)	Maximum Arresting-Hook Axial Load (Lb)	Maximum Long. Decel (G)	Maximum Purchase-Tape Tension (Lb) Port	Maximum Purchase-Tape Tension (Lb) Stbd	Runout (Ft)	Pendant History No. of Events Used		Remarks
						GOODYEAR (CONTINUED)					
						35-FOOT OFF-CENTER TO PORT TESTS					
152	3,850	24 May	130	40,500	1.52	32,100	24,600	840	9	1	Aluminum connectors
153	3,851	"	141	41,500	1.65	32,500	32,500	850		2	
154	3,852	25 May	150	48,300	1.96	36,200	27,500	865		3	
155	3,853	"	149	55,300	2.10	35,900	33,000	865		4	
156	3,854	"	165	68,200	2.53	41,300	42,600	885		5	
157	3,855	"	162	63,800	2.47	39,300	44,600	880		6	Pendant still usable
						ACCO ENERGY-ABSORBING STAINLESS-STEEL DECK PENDANTS					
						ON-CENTER TESTS					
24	3,663	29 Oct	133	45,500	1.60	22,700	23,400	855	1	1	
25	3,664	30 Oct	118	40,300	1.37	20,800	21,600	840		2	
26	3,665	"	132	47,600	1.51	23,900	24,600	855		3	
27	3,667	5 Nov	151	57,500	2.26	32,300	33,200	865		4	
28	3,668	6 Nov	152	58,700	2.05	33,100	34,900	865		5	Pendant had excessive flats
29	3,669	"	135	42,400	1.75	27,900	28,700	855	2	1	
30	3,670	"	141	51,200	1.87	30,600	31,800	855		2	
31	3,671	"	159	66,600	2.58	36,300	37,800	875		3	
32	3,672	9 Nov	145	55,500	1.80	30,200	30,600	860		4	
33	3,673	"	165	70,400	2.90	38,600	39,000	880		5	
34	3,674	"	165	72,500	3.01	38,400	39,600	880		6	
35	3,675	"	167	75,000	2.74	39,700	40,000	880		7	Pendant had excessive flats
36	3,676	16 Nov	158	65,800	2.41	NV	37,100	875	3	1	
37	3,677	"	172	73,800	2.65	37,900	41,400	885		2	
38	3,678	"	170	76,200	2.67	35,600	40,300	885		3	
39	3,679	17 Nov	175	77,200	3.01	41,100	43,600	890		4	Pendant had excessive flats and
40	3,680	"	181	78,500	2.92	41,200	43,200	895	4	1	broken wires
41	3,695	7 Dec	182	76,500	3.15	41,200	43,100	890		2	Pendant had 3 broken wires in 1 strand
42	3,696	"	189	80,700	3.45	42,400	42,900	900	5	1	Pendant had 3 broken wires in 1 strand
43	3,697	"	190	76,200*	3.33*	39,800*	44,200*	∞	6	1	Pendant damaged when stbd tape failed
44	3,698	8 Dec	190	82,700	3.40	43,800	43,100	900	7	1	Pendant had 1 broken strand
133	3,830	5 May	203	85,400	3.24	48,300	45,800	925	8	1	
134	3,831	"	207	91,100	3.50	52,600	48,300	930		2	Pendant had 4 broken wires in 1 strand
135	3,832	"	197	83,700	3.04	40,300	42,400	920	9	1	
136	3,833	7 May	219	100,700	3.72	59,200	60,300	935		2	Pendant had excessive flats
137	3,834	"	224	102,000	3.85	56,600	59,700	940	10	1	
138	3,835	"	216	NV	NV	NV	NV	∞		2	Pendant failed when port tape failed
						35-FOOT OFF-CENTER TO PORT TESTS					
158	3,856	25 May	132	45,500	1.59	27,700	25,900	840	11	1	
159	3,857	26 May	138	47,500	1.84	28,500	27,600	850		2	
160	3,858	"	150	62,700	2.28	36,300	34,300	860		3	
161	3,859	"	150	63,200	2.48	36,800	34,100	860		4	
162	3,860	"	160	66,700	2.48	42,500	37,500	875		5	Pendant had 15 broken wires
163	3,861	"	161	69,200	2.61	43,000	34,200	875	12	1	Pendant still usable

* Maximum loads occurred before failure.
NV = No value

APPENDIX B - APPLICABLE NATF DISCREPANCY REPORTS (BLUE SHEETS)

NATF Blue Sheet		NAEC	
No. and Date	Discrepancy and Action Taken	Date	Reply/Action
	Following 231-knot arrest of 25,000-pound deadload at RSTS No. 5		
E-28-72 17 Mar 71	Inner race of port and stbd energy-absorber upper bearing cracked. Plan to replace bearings.	30 Mar 71	Info noted.
E-28-73 17 Mar 71	Stbd energy-absorber rotor and stator blades extensively damaged. Inspection indicated inboard portion of filler plate torn loose because inboard pipe, NAEC PN A316316-8, of filler plate not properly welded to bottom of absorber housing. Plan to repair energy absorber.	30 Mar 71	Since cause of failure was improper weld, no change in welding procedure is considered necessary.
E-28-74 17 Mar 71	Port and stbd energy-absorber covers dished outward approx 1/8 and 1/2 inch respectively. Distortion of stbd unit cover exceeded that of port unit because of effects of filler plate failure. Plan to repair each cover.	30 Mar 71	Info noted.

Naval Air Test Facility (Report
NATF-EN-1114)
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UNCLASSIFIED

1. Arresting gear
   a. E-28
   b. Emergency
   c. Shorebased
2. Acft rcvy eqpt
3. Deck pendants
   a. Low-modulus nylon
   b. Energy-absorbing sst
4. Nylon-pendant-to-purchase-tape connectors

USAF MIPR
FX-2826-70-05259

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NAVEXOS-5070/3A